Swami Ramanand Teerth Marathwada University, Nanded-431606 (M.S.)

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■ Research Topic ■

"Synthesis, characterisation and morphological studies on SPEEK blended with MXene hybrid membrane for PEM fuel cells"

Submitted by
Mr. Dinkar Digambarrao Satonkar
Research student
Research centre
NES, Science College, Nanded
Cell No. 9604474200
Email: dinkarsatonkar@gmail.com
Category – OPEN

Under the Guidance of
Dr. Anil Ganpatrao Gacche
HOD, Department of Physics
Vasantrao Naik Mahavidyalaya, Vasarni,
Nanded-431603
(Attached to research centre NES Science college, Nanded)
Cell No. 8379830978
Email: anilgachhe@gmail.com

Abstract:

In fuel cell applications, the proton exchange membrane (PEM) is the major component where the balance among dimensional stability, proton conductivity, and durability is a long-term trail. With the rapid growth and development of proton-exchange membrane fuel cell (PEMFC) technology, there has been increasing demand for clean and sustainable global energy applications. The polymer composite membranes exhibit excellent features regarding water uptake, ion exchange capacity and proton conductivity than the pristine PES membrane.

In spite of various research studies, the commercialization of fuel cells are still facing hiccups. One such hiccup is the proton conduction stability, cost and environmental issues of proton exchange membrane made from Nafion. Hence keeping this issue in mind, we are planning to synthesise a blended membrane which serves as promising replacement for Nafion.

The aim of the present research work is to synthesize, characterize and study the morphology of polymer electrolyte membranes that can act as a possible replacement for Nafion. With this concept in mind, the blend of sulfonated poly ether ether ketone (SPEEK) and Mxene are considered of high potential for the fabrication of proton exchange membrane application which may be considered as most promising alternative to commercial membranes.

The proton exchange membrane (PEM) synthesis will be done using sulfonated poly ether ether ketone (SPEEK) blended with MXene.

This work will focus on the development of a hybrid composite proton exchange blended membrane, MXene-SPEEK, which will be used for high proton conductivity.

Synthesized hybrid blended membrane materials will be characterized by different tools for e.g. powder XRD, Wide-angle X-ray diffractometry (WXRD), FT-IR, SEM, FE-SEM, AAS etc. The synthesized products are further modified in view of their potential application in the field energy production with the help of fuel cells.

Key Words: Fuel cells (FCs), proton exchange membrane (PEM), sulfonated poly ether ether ketone (SPEEK)

Introduction:

Fuel cells (FCs) serve to convert fuels such as hydrogen into electric power in an efficient and environment friendly manner. Proton exchange membrane fuel cells (PEMFCs) are compact, lightweight with high current densities and hence are advantageous over other fuel cells. Compared to other sources of energy, PEM fuel cells have many advantages. They act as eco-friendly renewable energy systems and can be stored for application as a single cell or many cells combined together, forming a cell stack to obtain higher voltage and electricity. PEM fuel cells have advantage of burning in reduced temperature compared to other systems.

Compared to other energy generating mediums, fuel produced from PEM fuel cells is considered clean and stable. They are reliable for a wide range of portable and stationary power uses. In addition to using PEM fuel cell as a standalone power generator, the PEM fuel cell can also be implemented with a renewable energy system for energy storage application.

A wide range of materials as a substitute for Nafion membrane have been described. A major development in this regard is seen in the use of sulfonated aromatic polymer (sulfonated polyimide), sulfonated poly ether sulfone (SPES) , sulfonated poly (phenylene oxide) (SPPO) and sulfonated poly ether ether ketone (SPEEK). Recently, SPEEK have shown potential applications for fuel cell due to their cost effectiveness and improved chemical stability. However, SPEEK membranes suffered a substantial swelling ratio due to high degree of sulfonation which ultimately affects their mechanical strength.

To overcome this drawback, polymer blending may be considered as an effective procedure to alter and improve the membrane properties and performance. However, it is also reported that the membranes fabricated by blending two kinds of sulfonated polymers resulted in high proton conductivity, good performance and miscible structure.In order to improve the performance of PEMs in the fuel cells, the blending of SPEEK and Mxene compounds is proposed in this research work..

This work proposes the efforts to synthesis, characterise, and morphological study of the blended SPEEK and Mxene compounds proton exchange membranes (PEMs), and morphology were investigated in detail. The synthesis and characterization of these blended membranes will be confirmed by different characterization methods. The proton conducting performance of these prepared blended membranes will be compared with commercial membrane Nafion 117 or other commercially used Nafion membrane.

Review of Research:

Hydrogen production via water electrolysis is a sustainable solution for solving various issues related to energy and the environment. Recently, a very impressive integrated energy production system was introduced, wherein an overall water splitting system is driven by a zinc-air battery and the produced H_2 is directly supplied as feedstock for the hydrogen fuel cell. Therefore, proton exchange membrane (PEM) water electrolysis has now become a favourable approach for high-purity hydrogen production via the decomposition of water in a simplified manner using a compact system. In PEM water electrolysis, water is electrochemically split into hydrogen and oxygen via two spontaneous reactions (oxidation and reduction) when electricity is applied to the system. First, oxidation occurs at the anode with the release of H^+ ions and O_2; then, the H^+ ions pass through the PEM towards the cathode to form H_2 as the final product. [2,6]

This process does not generate harmful or hazardous by-products during the reaction. In this system, the PEM plays a crucial role in the transfer of H^+ ions and acts as a barrier for electrons to allow only H^+ ions to pass in the water electrolysis cell to produce H_2. [10]

Although a PEM is available commercially, Nafion (a perfluorosulfonate acid membrane), it is a polytetrafluoroethylene (PTFE)-based polymer and can cause many hazardous effects on the environment because of the presence of fluoro groups. Therefore, many hydrocarbon-based polymers have been studied as PEMs instead of Nafion. [7]

Considering the need for cleaner and harmless materials, sulfonated poly ether ether ketone (SPEEK), which is a hydrocarbon-based polymer, is an attractive membrane material that contains a hydrophilic domain attached to the hydrophobic chain. This makes it an appropriate candidate for PEM because of its high mechanical and thermal stability, chemical resistance, and high oxidative stability. Further, when it is used as a PEM, SPEEK showed a good ion exchange capacity and proton conductivity, which makes it suitable for use as an H^+ ion exchange membrane in water electrolysis. [12]

However, previous research shown that SPEEK membranes tend to swell excessively or dissolve at elevated temperatures, and their proton conductivity is comparatively lower than that of Nafion membranes; this can be further improved by incorporating inorganic fillers

and/or other polymers to form SPEEK composite membranes. Some inorganic oxides such as SiO_2, Al_2O_3, ZrO_2, TiO_2 , amine functionalized carbon nanotubes, and sulfonated carbon nanotubes have been utilized as fillers to increase the physical and chemical properties and the proton conductivity of SPEEK membranes. [3,8,9]

However, Two-dimensional (2D) MXene has emerged as an exciting material that has been applied in a wide range of applications. MXene represents the carbides, nitrides, and carbonitrides of transition metals. MXene, which is denoted as $Ti_3C_2T_x$, [12] can serve as a filler or a reinforcing agent for polymers owing to its distinctive characteristics such as excellent conductivity; high chemical, thermal, mechanical strength; and hydrophilic nature; which enable the development of surface termination.

Thus for, various applications of MXene have been reported as it can be used in energy storage devices as a supercapacitor electrode, an electrocatalyst for hydrogen evolution reaction in water splitting, co-catalyst in photocatalysis, in the preparation of flexible and conductive nanocomposite films, and as a filler embedded into SPEEK/Nafion/chitosan polymers and used as the composite PEM for hydrogen fuel cells.

Objectives of The Study Present Investigation:

The objectives of the research work carried out towards fulfilment of Ph.D. degree are reproduced below for highlighting the concepts, which will be described and discussed in this thesis.

- To investigate the preparation of a hybrid composite PEM for various synthesis parameters such as blending concentration, high proton conductivity, source material, performance stability, temperature, dimensional stability and morphological studies of blended proton exchange membrane.
- To investigate the comparison of performance stability in view of high proton conductivity of Sulphonated poly ether ether ketone and Mxen hybrid blended membrane with Nafion membrane.
- To characterize the sample of said blended PE membrane by various techniques such as powder XRD, Wide-angle X-ray diffractometry (WXRD), FT-IR, SEM, FE-SEM, AAS.

- To study about possibilities of said PE membranes for use in the fuel cells as an effective mode of energy to substitute the conventional energy sources which are proved as a great threat for the environment.

Significance of Study:

As can be seen from the above discussion, synthesis of blended, hybrid proton exchange membranes for effective use in fuel cells, characterization and morphological study are very active area of fundamental, applied and commercial research. The outcome of research study will give valuable contribution in the field of energy sources and material science.

Methodology:

A wide range of materials as a substitute for Nafion have been described. A major development in this regard is seen in the use of sulfonated aromatic polymer and sulfonated poly ether ether ketone (SPEEK).

In order to improve the performance of PEMs, the blending of SPEEK and Mxene is proposed. Among the non-fluorinated membranes materials, sulfonated poly (ether ether ketone) is another ion polymer that has high mechanical and thermal stability along with good proton conductivity. Some of the properties of individual polymer can be used as a basis to device the novel membranes with desirable performance by blending.

PEEK polymer is proposed to prepare by the process of sulphonation by using some concentrated acids. Blended membrane of SPEEK and Mxene is proposed to be fabricated by process of continuous stirring and casting on the glass plate.

For characterization we are planning to employ the various processes such as powder XRD, Wide-angle X-ray diffractometry (WXRD), FT-IR, SEM, FE-SEM, AAS.

We try to employ attenuated total reflectance (ATR) with FTIR spectrometer to confirm the fabrication of SPEEK/SPPO blended membranes.

Herein, scanning electron microscopy (SEM) will be utilized to investigate morphological features of surfaces and cross-sections of the fabricated SPEEK, and blended SPEEK-Mxene membrane structure.

The proportion of water uptake and membrane swelling of blended membrane will also be compared with the pristine membrane such as Nafion 117.

Importance of Study:

- Selected research topic is a step towards an ecofriendly alternative to fuels and related to, local to global problems.
- Fuel cells are used as primary and backup for commercial, industrial and residential purpose. They are also used to power fuel cell vehicles, including automobiles, buses, trains, boats, motorcycles etc.
- This study will prove to be sustainable approach towards green energy.
- New synthesis techniques are considered for preparation of value-added proton exchange membrane.
- Fuel cells provide clean energy and emit no pollution. Moreover, it also offers high efficiency and zero emissions.
- Compared to batteries and internal combustion generators, fuel cells save money. They eliminate the need to change, charge, and manage batteries.

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Mr. Dinkar Digambarrao Satonkar
Research Scholar

Submitted through:
Dr. Anil Ganpatrao Gacche
Research guide